

Open Loop Control Of Series Parallel Resonant Converter

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Abstract— Resonant converters are desirable for power conversion due to their comparatively smaller size and lower power losses resulting from high-frequency operation and inherent soft switching. Among all the topologies of the resonant converters, the series-parallel resonant converter (SPRC) is known to have the combined merits of the series resonant converter and parallel resonant converter. The converter can regulate the output voltage at a constant switching frequency even for a change in load resistance from full load resistance to infinity while maintaining good part load efficiency. The purpose of this project is to design a closed loop controller for the phase-controlled series parallel resonant converter (PC SPRC). The open loop analysis and closed loop control has been provided in this paper.

Index Terms—Digital control, modeling, phase-shift control and resonant power conversion.

I. INTRODUCTION

Power electronic systems are widely used today to provide power processing for applications ranging from computing and communications to medical electronics, appliance control, transportation, and high-power transmission. The associated power levels range from milliwatts to megawatts. These systems typically involve switching circuits composed of semiconductor switches such as thyristors, MOSFETs, and diodes, along with passive elements such as inductors, capacitors, and resistors, and integrated circuits for control. To reduce the size of power supplies intended for use in modern computing systems, it is desirable to raise the operating frequency to reduce the size of reactive components. To reduce the higher switching losses resulting from higher frequency operation, resonant power conversion is receiving renewed interest.

Resonant power conversion technology offers many advantages in comparison with PWM one. Among them are low electromagnetic interference (EMI), low switching losses, small volume and weight of components due to high operating frequency, high efficiency, and low reverse-recovery losses in diodes because of low di/dt at turn-off. However, most frequency-controlled resonant converters, suffer from a wide range of frequencies which is required to regulate

output voltage against load and line variations. This makes it difficult to filter EMI and effectively utilize magnetic components. As a remedy for these problems, full bridge topologies of phase-controlled resonant inverters and converters have been proposed

Resonant converters are desirable for power conversion due to their comparatively smaller size and lower power losses resulting from high-frequency operation and inherent soft switching. Among all the topologies of the resonant converters, the series-parallel resonant converter (SPRC) shares the advantages of both the pure series converter and pure parallel converter [1]. To regulate the output of an SPRC, frequency control or phase control are usually used. The frequency control can be used in a half-bridge configuration. The phase control requires a full-bridge circuit. It allows, however, for a constant frequency operation. Some of the phase-controlled converters, for example, the phase-controlled SPRC (PC SPRC) introduced in [2], are capable of providing inductive loads for the switching devices in both legs of the inverter bridge. Thus, the reverse recovery currents through the antiparallel diodes in the switches are minimized, and the power losses are reduced.

The main advantage of series resonant converter is that the series resonant capacitors act as a dc blocking capacitor. Because of this fact this converter is used in full bridge arrangements without any additional control to control unbalance in the power FET switching times and forward voltage drops. The main advantage of parallel resonant converter is that it is extremely desirable for applications with short circuit proof. Also in this converter, the current carried by the power FET's and resonant components is relatively independent of load. The series parallel resonant converter combines the above said advantages.

II. PROPOSED CIRCUIT DIAGRAM

The PC SPRC consists of two identical series-parallel inverters. Each inverter is composed of two switches with their anti parallel diodes and a series-parallel resonant circuit with a shared parallel-connected capacitor $2C_p$. These two resonant circuits form an overall resonant tank, which is symmetrical with respect to $2C_p$. The dc

load R is connected to this resonant tank through a rectifier and an output filter.

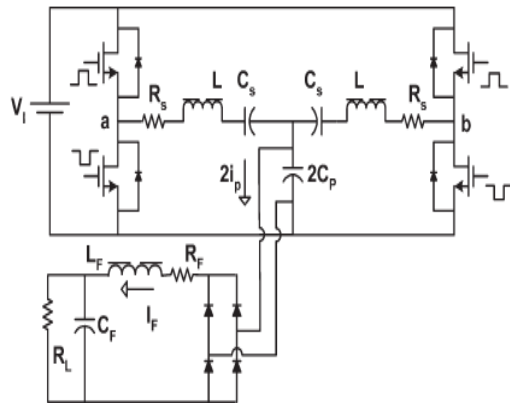


Fig.1. Circuit diagram

If the switching frequency is fixed at a value close to the resonant frequency, the output voltage V_o can be regulated against load and line variations by varying the phase shift between the voltages that drive inverter 1 and inverter 2 while maintaining a fixed operating frequency and inductive loads for both pairs of switches. For inductively loaded switching legs, zero-voltage switching can be accomplished by adding a shunt capacitor in parallel with one of the switches in each leg and using a dead time in drive voltages of MOSFET's. The converter is suitable for medium-to-high power applications with the upper switching frequency limit of 150 kHz.

A Assumptions

The analysis of the PC SPRI of Fig. 1 begins with the following simplifying assumptions:

- 1) The loaded quality factor Q_L of the inverter is high enough so that the currents i_1 and i_2 are sinusoidal.
- 2) The power MOSFET's are modeled by switches with ON-resistances R_{DS} .
- 3) The reactive components of the resonant circuits are passive, linear, time invariant, and do not have parasitic resonances.
- 4) Components of both resonant circuits are identical

B Block Diagram

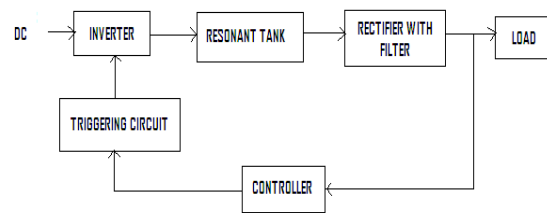


Fig.2. Block Diagram

The DC supply is given to the series parallel inverter with resonant tank which produces alternating voltages and currents due to resonance. This AC output is fed to a class-D voltage driven rectifier to obtain rectified output. The resonant converter is used in low voltage power supply applications

C Simulation Results

Simulation is done in MATLAB programming language for the above mentioned problem and the research is going on in to get absolute result. The simulation model are shown in the fig 3,4 and 5

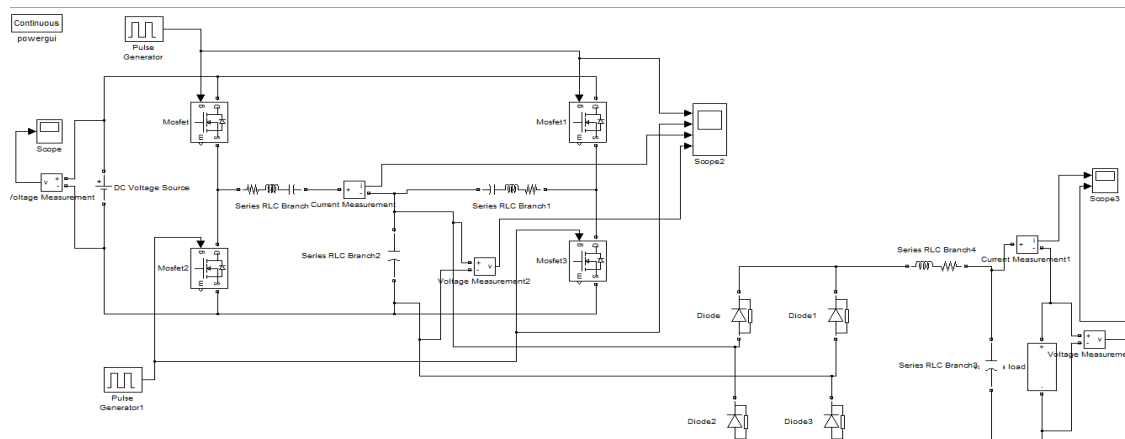


Fig.3. Simulation circuit with variable load

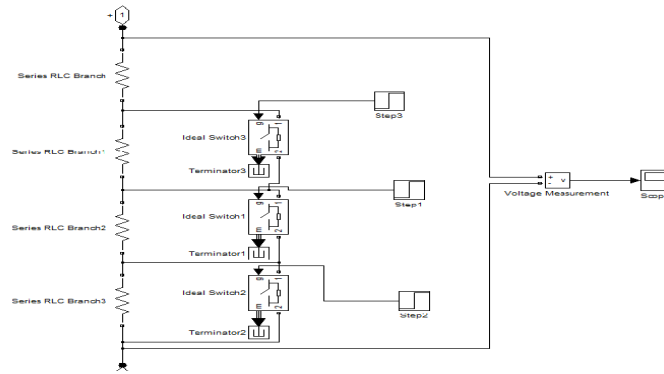


Fig.5. Series Variable Load Producing Circuit

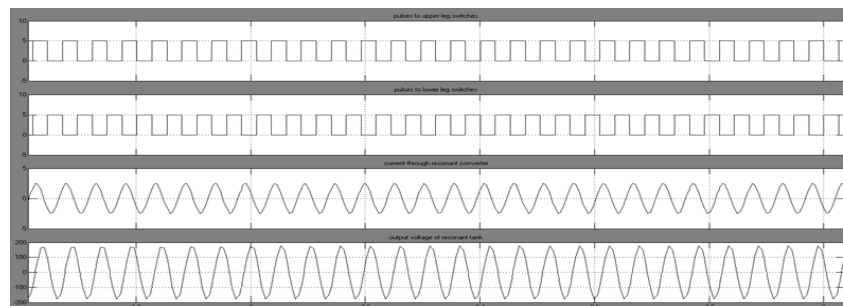


Fig.6. Simulation Result

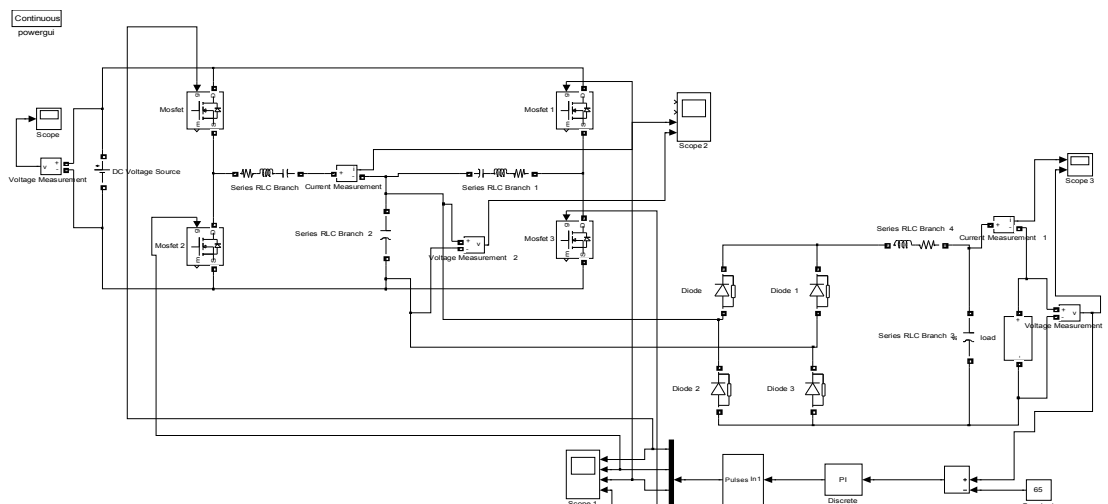


Fig.7. Resonant Converter Circuit With Controller

respectively. The rectified output is constant for fixed load and it varies for variable load. The analysis shows that the combination series-parallel converter can run over a large input voltage range and a large load range (no load to full load) while maintaining excellent efficiency when compared to series and parallel resonant converters analysed separately

D Experimental Results

A phase controlled series parallel resonant converter has been simulated with variable load. The natural resonant frequency is 18.268 kHz for this converter, and the switching frequency is 1.05 times the resonant

frequency, or 19.181 kHz. The designed resonant circuit resistance, series inductance and series capacitance values are 5 Ω , 1.1 mH and 0.1 μF respectively. The parallel capacitance value in the resonant tank is 0.22 nF. The waveforms of the voltage across the parallel capacitor C_p and the current through the resonant circuit of the inverter is shown in Fig.4. It can be seen that these waveforms are sinusoidal over a wide range of the load resistance, which confirms the assumption 4). The simulation has provided a rectified output voltage of 100 V for fixed resistive load of 100 Ω . The output voltage and output current responses for

the step changes in load resistance from $200\ \Omega$ to $50\ \Omega$ is shown in Fig.7. The output voltage and current responses for step change in resistance from $150\ \Omega$ to $100\ \Omega$ is shown in Fig.8. It can be seen Fig.9. that the rectifier output voltage is maintained constant at 65 V using PI controller.

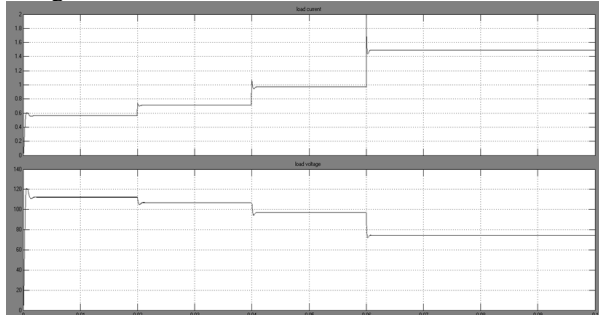


Fig.8. Rectifier Output for variable load

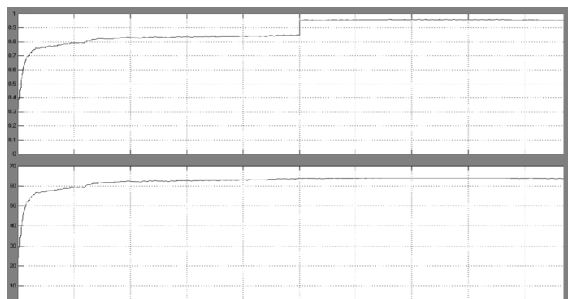


Fig.9. Controller Rectifier Output

E. Applications

- In induction heating
- Capacitor charging
- Battery charging
- Semiconductor laser diode drivers
- Sonar transmitter
- Telephone equipment
- Ultrasonic generators
- Fluorescent lighting

III. CONCLUSION

A new phase-controlled series-parallel resonant converter has been introduced which provides constant DC power supply for various applications. An attempt is made to analyse the series parallel resonant converter under open loop condition and closed loop control and the simulation results has been obtained for varying load conditions. The essential control task is to

implement a control algorithm that generates the control signals to the converter based on measured output or state signals from converter as in [4]-[7]. The controller must generate these control signals fast enough to retain control of the plant. Therefore, speed can be a severe limitation on the controller for systems with dynamics at high frequency. The use of microprocessors as a replacement for conventional analog controllers to implement discrete controllers, therefore, has advantages and limitations. The advantages are flexibility, programmability, and the ability to handle other supplementary functions like start up and protection. On the other hand, since the controller must operate in real time, there is a speed limitation when controlling a very high speed system.

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